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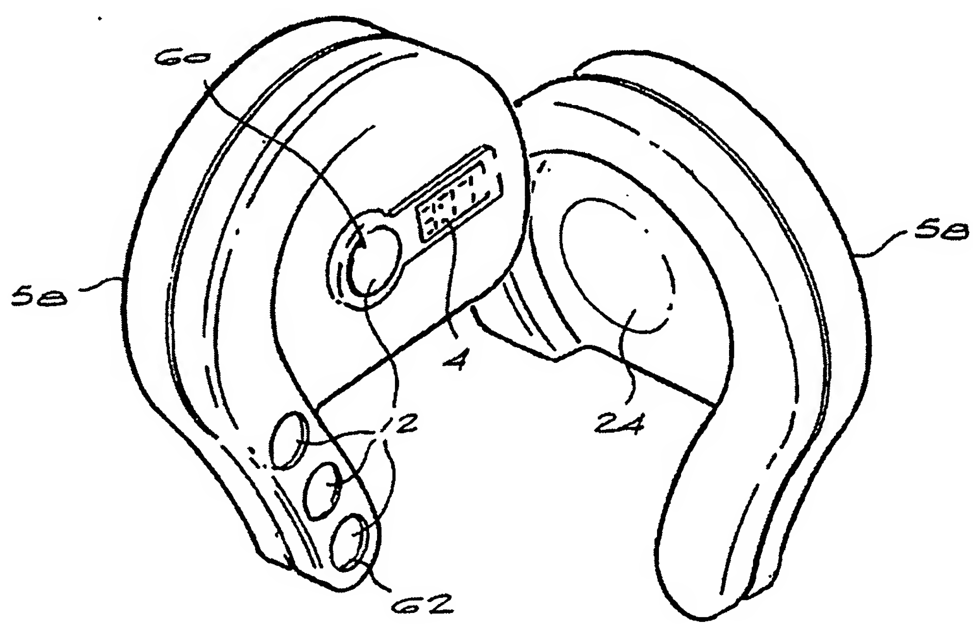
(54) Title: APPARATUS FOR DETERMINING WHEN A SWIMMER TURNS



(57) Abstract

The apparatus comprises a portable housing which can be worn by a swimmer, for example in or on the swimmer's ear. A magnetic sensor in the housing detects a change of orientation of the swimmer relative to the earth's magnetic field when the swimmer turns and generates a turn signal which is sent to a processor. Alternatively, a shock sensor arranged to be strapped to the swimmer's ankle, for example, can be used to transmit a signal to a processor in the housing. The processor generates an output signal in the form of selected stored speech components to indicate to the swimmer parameters such as total elapsed time, number of laps or lap time.

APPARATUS FOR DETERMINING WHEN A SWIMMER TURNS

BACKGROUND OF THE INVENTION

THIS invention relates to apparatus for determining when a swimmer turns, typically at the completion of a length of a pool.

When training, swimmers need to keep count of the number of laps swum, as well as the time per lap, and the elapsed time. Knowing the number of strokes per lap is also useful for the swimmer.

In prior art systems, a swimmer is required to press a button at every turn to keep count of the number of laps, and to look at a display in order to obtain relevant information.

It is an object of the invention to provide apparatus for determining when a swimmer turns at the completion of a lap without requiring the swimmer to press any buttons at the time of turning. It is also an object of the present invention to provide information to a swimmer without requiring the swimmer to look at a display.

SUMMARY OF THE INVENTION

According to the invention there is provided apparatus for determining when a swimmer turns comprising:

a portable housing;

a sensor in the housing for detecting turning of the swimmer and for generating a turn signal in response thereto;

processor means in the housing and responsive to the turn signal to generate an output signal; and

output means responsive to the output signal to generate an output perceptible to the swimmer and indicative of at least one of the number of laps sum by the swimmer, the time elapsed since a predetermined time, and the time per lap.

The sensor may comprise at least one magnetic field sensor.

Preferably the sensor comprises three magneto-inductive field sensors which are arranged orthogonally.

Alternatively the sensor may comprise an acceleration sensor or a shock sensor.

The acceleration sensor or shock sensor may be located with the processor means in the housing.

Alternatively, the acceleration sensor or shock sensor may be arranged to be worn on a limb of the swimmer. the apparatus then including transmitting means for transmitting the turn signal from the sensor to the processor means.

The output means may comprise a storage device for storing data corresponding to predetermined words, and an audio output device. so that an audio signal comprising one or more words is output to the swimmer when turning of the swimmer is detected.

The storage device and the audio output device are preferrably arranged to be controlled by the processor means, which accesses the storage device to retrieve data corresponding to selected words to be output to the speech output device.

The housing is preferably waterproof and sized and shaped to be placed in proximity to the swimmer's ear, so that the audio output device will output speech signals audible to the swimmer while the apparatus is in use.

The apparatus may include a display for displaying selected parameters to the swimmer, the selected parameters including at least one of the number of laps swum by the swimmer, the time elapsed since a predetermined time, and the time per lap.

The processor means is preferably a microprocessor having associated input means arranged to allow a user to input commands to the microprocessor.

The apparatus preferably includes a memory device for storing data relating to predetermined user defined parameters and a communication device for

downloading the stored data to an external device.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic block diagram of the electronic circuit of a first embodiment of apparatus according to the invention;

Figure 2 is a schematic block diagram illustrating an arm movement sensor to be used in conjunction with the circuit illustrated in Figure 1;

Figure 3 is a schematic block diagram of the electronic circuit of a second embodiment of the invention; and

Figure 4 shows a housing in which the circuit of Figures 1 and 3 is placed.

DESCRIPTION OF EMBODIMENTS

The main purpose of the present invention is to determine automatically when a swimmer turns at the completion of a lap, usually at the side of a pool. This event can then be used to determine a variety of useful data, such as the number of laps swum, split time for last completed lap, elapsed time since start and distance swum since start. Another purpose of the present invention is to communicate this information to the swimmer audibly while swimming.

Figure 1 illustrates a first embodiment of the invention. The main

components used for this embodiment are:

a processor 2;
an LCD display 4;
an audio transducer 6;
sensors 8;
a serial electrically erasable programmable read only memory (EEPROM) 10;
input switches 12;
a battery 14; and
a PC interface 16.

The three sensors are magneto-inductive sensors such as the SEN-M magneto-inductive sensor supplied by Precision Navigation. This sensor operates by the inductance of the sensor varying depending on the applied magnetic field strength. These sensors are used in a magnetometer arrangement to accurately measure orientation changes as a result of changes sensed in the orientation of the earth's magnetic field relative to the sensor.

An operational amplifier 18 is arranged as a Schmitt trigger, with one of the three magneto-inductive sensors connected in its feedback path, thereby forming a relaxation oscillator circuit. This causes the operational amplifier 18 to oscillate depending on the inductance of the particular sensor. Three CMOS type CD4066 transmission gates, TG1, TG2 and TG3 allow the processor 2 to select which of the sensors are to be used at any time. The three sensors are arranged orthogonally so that two of them are in the same plane but offset 90 degrees to one another and the third is mounted vertically relative to this plane. The three sensors are therefore continuously and

sequentially enabled to provide a frequency output from the oscillator indicating the magnetic field strength in the relevant plane.

A highly integrated Motorola MC68HC05L25 microprocessor is used as the processor 2. The microprocessor 2 contains its own internal program memory. read/write data memory, LCD display interface, clock. frequency counter, analog to digital converter and external interfaces. A sequence of program instructions (the program) is loaded into the microprocessor's program memory which executes the tasks allowing it to function.

The magneto-inductive sensor frequencies are measured by an event counter function. The frequency changes sensed as the device is rotated in the horizontal plane indicate heading. This heading is calculated as arctangent (Y frequency/X frequency). Tilt variations also affect the sensors and the vertical magnetic component is therefore measured and used to correct the sensed direction via a simple cosine rotation function. Since only a change of direction which is close to 180 degrees needs to be sensed, exact heading information is not required, and a 180 degree change in direction will be detected as a turn. The calculated heading is also averaged over a period of 1 second to avoid short-term changes resulting from tilt.

Alternatively, a tilt sensor (not shown) may be added to provide additional tilt correction information to the microprocessor 2. This tilt sensor will also provide a means of sensing the swimmer's strokes. Typically, a dual axis tilt sensor, such as the ADXL202 from Analog Devices, is used to detect head sideways movement, which indicates breathing and strokes when swimming freestyle and backstroke, as well head up and down movement, which indicates strokes when swimming breaststroke and butterfly. The tilt sensor must be mounted to be as close as possible to the horizontal with

respect to the water surface when the swimmer is wearing the device placed over his/her ear while swimming, and without the head being tilted in either a sideways or up and down direction. The ADXL202 sensor is sensitive to both static acceleration, such as gravity, and dynamic acceleration, due for example to the head being turned. It provides two digital signals with pulse width modulated outputs in a range of + 2G, indicating acceleration on the particular axis. This pulse width is then measured against the pulse period by the microprocessor 2, which will produce an 8 bit value indicating both static and dynamic acceleration.

The microprocessor 2 is also able to output speech signals to the swimmer. Data corresponding to the speech is stored in the attached EEPROM 10 in the widely used and well known Advanced Delta Pulse Code Modulation (ADPCM) form at 9.6 k samples/second. Each word of speech is stored as one of up to 256 phrases, each phrase containing as a first byte its 8 bit address, and a 16 bit length stored in 2 bytes. A fast SDI interface bus is used between the EEPROM 10 and the microprocessor 2.

The program will cause the phrase location in the EEPROM to be located using a table listing the actual addresses for each phrase. The microprocessor 2 fetches data sequentially from this address, starting with the phrase address for checking purposes, and then the phrase length word. The microprocessor 2 fetches phrase data sequentially up to the end of the stored data according to the length of each word. Each speech byte fetched is handled in 4 bit nibbles. The program calculates the 8 bit value reflecting the speech analog value at that point from the 4 bit delta data. The 8 bit data is continuously output as a pulse width modulation signal on the PA7 pin of the microprocessor 2. This is achieved by sequentially shifting out from the least significant bit each of the 8 data bits.

An external integrator consisting of a resistor and a capacitor converts this to an analog value, which is then amplified by a TLC3702 operational amplifier 20. This operational amplifier 20 has an NPN transistor 22 buffered output driving the speech output to a small moving coil loudspeaker 24.

The stored phrases typically contain numerics, such as 'nought', 'one', 'two', up to 'ten', and words such as 'lap', 'laps', 'total', 'time' 'split', 'rep', 'go', 'last', 'distance', 'yards', 'meters', 'on', 'off', 'started' and 'stopped'. Other words which may be found useful for a particular variation of this embodiment may also be included.

The microprocessor 2 has four associated control buttons 12 which are identified as follows:

On/Off	to switch the device on/off;
Start/Stop	to start and stop a measurement cycle;
Mode	to change the operating modes;
Set	to select a particular option or setting.

The microprocessor 2 contains an internal timer, which is used to clock time in 0.1 second steps. This timer is cleared by the swimmer, and started by activating the start/stop button.

The microprocessor 2 functions by denoting every change in direction as an event "Turn". In the normal mode this event will result in various parameters, such as number of laps, time of last lap, total elapsed time and distance since start being calculated and stored. The calculated data

required by the swimmer after each lap is then used to retrieve the correct phrases from the EEPROM for conversion to speech, for example, 'total' 'laps' 'two' 'four' to indicate 24 laps completed.

The personal computer (PC) interface 16 is a simplex 125kHz transmitter and receiver operating at a low bit rate of 2400 bits per second. Data is transmitted by outputting 125kHz amplitude modulated data via a buffer 26 and a transmission gate 28 to a capacitor/coil combination 30, which is tuned to 125kHz. When receiving data, the transmission gate 28 is disabled. The 125kHz data is demodulated using a peak detector consisting of an operational amplifier 32, a diode 34 and a capacitor 36.

This same 125kHz receiver is also used to receive pulses from an arm movement sensor illustrated in Figure 2. The arm movement sensor is used to detect and monitor arm strokes, and is also used to automatically detect when a swimmer starts or stop swimming. The sensor is thin and compact and is attached to an elastic wrist strap. It is battery operated and contains a miniature shock sensor 40, which may be, for example, a PKGS-25LA device supplied by Willow Technologies Ltd. This particular shock sensor is selected for the sensitivity required to reliably detect arm forward extension, such as when the arm moves forward before entry when swimming freestyle, backstroke and butterfly, and when it is extended forward when swimming breaststroke.

A TLC3702 operational amplifier 42 amplifies the signal from the shock sensor 40. The negative going output from this operational amplifier firstly removes the reset signal from a counter 44, and is secondly inverted by a dual input NAND gate 46 in order to enable a resonator controlled oscillator, denoted generally by reference numeral 48. This oscillator uses a

500kHz ceramic resonator 50, and is based on a linearly biased Schmitt trigger NAND gate 52.

The counter 44 is an octal counter which divides the signal down. The output at Q1 of the counter 44 is the required 125kHz carrier frequency. This signal is gated with either output Q5 or Q6 of the counter 44 in order to send bursts of either 8 or 16 cycles of the 125kHz signal. This will allow two shock sensors to be used with the device and the device will simply detect in software whether the 125kHz burst is either 8 or 16 cycles long in order to differentiate between sensors. The arm movement sensor is set for 8 cycles of 125kHz carrier per burst. An inductor 54 and a capacitor 56 are tuned to 125kHz in order to transmit bursts of carrier to the main device described above.

A second embodiment of the invention is illustrated in Figure 3. The part of the apparatus illustrated in Figure 3 is similar to the apparatus of Figure 1 described above and like parts are denoted by like reference numerals. In this embodiment, the magnetometer is removed from the circuit and a leg shock sensor or accelerometer is used to determine when a swimmer turns at the side of a pool by measuring when the swimmer kicks off from the side of the pool. The shock sensor can be based on piezo shock sensing devices, such as the PKGS range supplied by Willow Technologies Ltd., and manufactured by Murata. These sensors sense acceleration, which means that other types of accelerometers, such as the dual axis ADXL202 from Analog Device can also be used.

The shock sensor or accelerometer can be mounted in the main unit illustrated in Figure 3 where it will interface directly to the microprocessor 2 after being amplified and buffered. In this case it is mounted so that it is sensitive to

acceleration in the forward direction. Alternatively, the sensor can be attached to a leg for additional sensitivity to the kicking motion when turning. In this case the sensor will contain the same circuitry as that used in the arm movement sensor described above with reference to Figure 2. However, it will be set to transmit 16 cycles at 125kHz each time a kick is detected. The sensor is mounted in a waterproof enclosure on an elastic strap and placed around one of the swimmer's ankles. In this variation, the sensitivity of the shock sensor is such that it does not detect and signal kicks from any of the swimming strokes, and a reception of bursts of pulses from the sensor therefore results in the Turn event as described above.

The circuitry of the apparatus described with reference to Figures 1 and 3 above is mounted in a waterproof housing 58 as illustrated in Figure 4. The housing 58 is typically made from a soft silicone rubber and fits over an ear of the swimmer. The housing 58 is made waterproof using O rings and rubber seals. In use, all or part of a swimming cap may cover the housing 58. The sound transducer 24 sits against the swimmer's ear, and the buttons 12 are somewhat recessed to avoid them being accidentally activated. The start/stop button 60 as well as the on/off button 62 can be easily reached while wearing the device, as these buttons may be needed while the apparatus is in use.

The liquid crystal display 4 is situated at the rear of the housing 58, and has 6 digits for time display and 4 digits for lap display. The liquid crystal display 4 also has the following icons:

- Yards symbol;
- Meters symbol;
- Modes icons:
  - Normal;

Set interval training:

- Set repeat time;
- Set laps per repeat;
- Set number of repeats;
- Set rest period;

Set pool length.

One important function that the invention is able to implement is the ability to control interval training by communicating with the swimmer. This is done by counting and communicating the number of repeats, indicating when a repeat has to start via a count down, communicating the swim time per repeat, and indicating when the particular interval exercise set has finished.

Thus it can be seen that the apparatus determines when a swimmer turns at the end of a lap without requiring the swimmer to press any buttons at the time of turning. It also provides information to a swimmer without requiring the swimmer to look at the display.

CLAIMS:

1. Apparatus for determining when a swimmer turns comprising:

   a portable housing;

   a sensor in the housing for detecting turning of the swimmer and for generating a turn signal in response thereto;

   processor means in the housing and responsive to the turn signal to generate an output signal; and

   output means responsive to the output signal to generate an output perceptible to the swimmer and indicative of at least one of the number of laps swum by the swimmer, the time elapsed since a predetermined time, and the time per lap.

2. Apparatus according to claim 1 wherein the sensor comprises at least one magnetic field sensor.

3. Apparatus according to claim 2 wherein the sensor comprises three magneto-inductive field sensors which are arranged orthogonally.

4. Apparatus according to claim 1 wherein the sensor comprises an acceleration sensor or a shock sensor.

5. Apparatus according to claim 4 wherein the acceleration sensor or shock sensor is located with the processor means in the housing.

6. Apparatus according to claim 4 wherein the acceleration sensor or shock sensor is arranged to be worn on a limb of the swimmer, the apparatus including transmitting means for transmitting the turn signal from the sensor to the processor means.

7. Apparatus according to any one of the claims 1 to 6 wherein the output means comprises a storage device for storing data corresponding to predetermined words, and an audio output device, so that an audio signal comprising one or more words is output to the swimmer when turning of the swimmer is detected.

8. Apparatus according to claim 7 wherein the storage device and the audio output device are arranged to be controlled by the processor means, which accesses the storage device to retrieve data corresponding to selected words to be output to the speech output device.

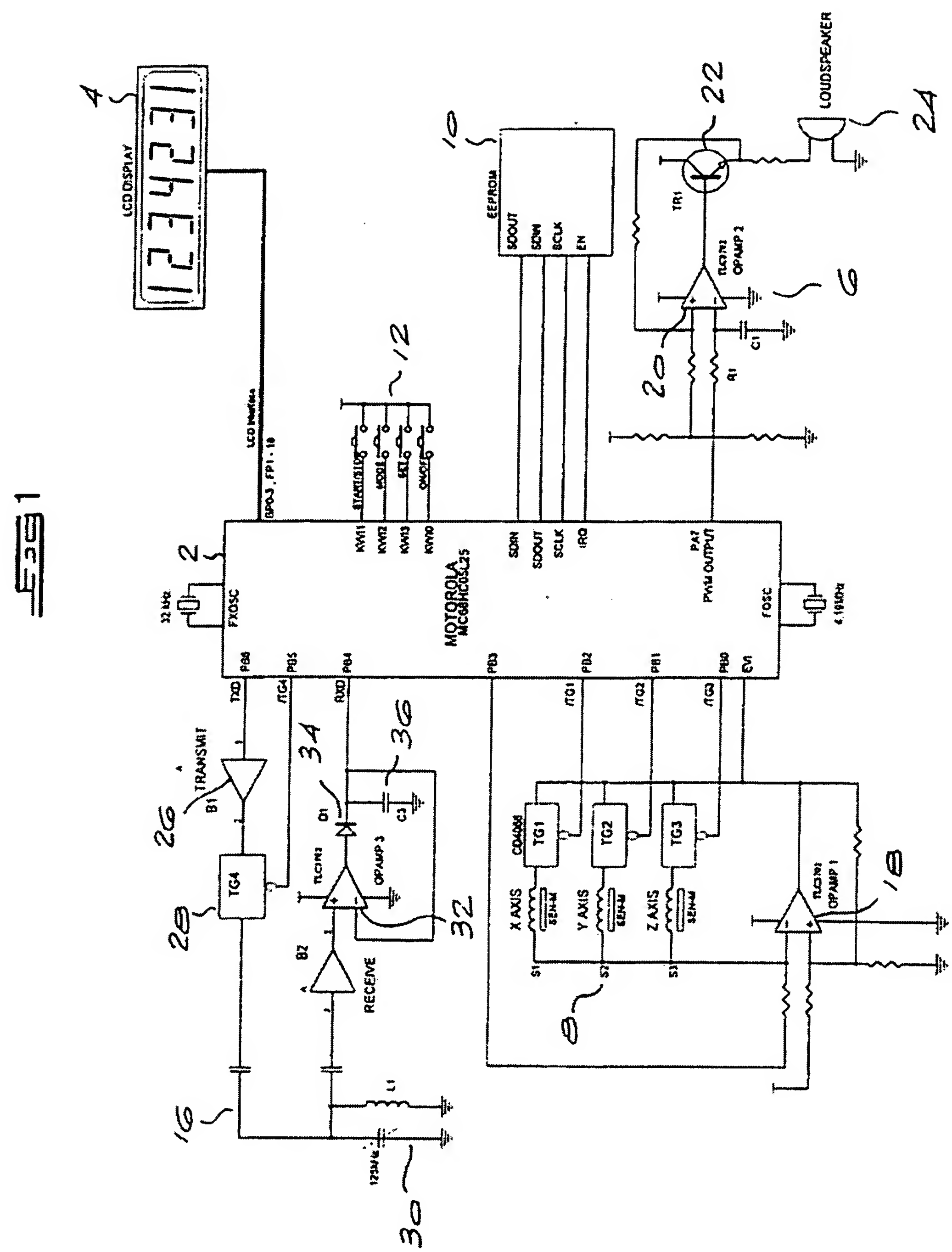
9. Apparatus according to claim 7 or claim 8 wherein the housing is waterproof and is sized and shaped to be placed in proximity to the swimmer's ear, so that the audio output device will output speech signals audible to the swimmer while the apparatus is in use.

10. Apparatus according to any one of claims 1 to 9 including a display for displaying selected parameters to the swimmer, the selected parameters including at least one of the number of laps swum by the swimmer, the time elapsed since a predetermined time, and the time per lap.

11. Apparatus according to any one of claims 1 to 10 wherein the

processor means is a microprocessor having associated input means arranged to allow a user to input commands to the microprocessor.

12. Apparatus according to claim 11 including a memory device for storing data relating to predetermined user defined parameters and a communication device for downloading the stored data to an external device.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SDOUT
SDIN
SCLK
EN
LOUDSPEAKER
TR1
OPAMP 2
C1
R1
START/STOP
MODE
SET
ON/OFF
MOTOROLA
MC68HC05L25
KWI1
KWI2
KWI3
KWI0
IRQ
PA7
PWM OUTPUT
FXOSC
FOSC
32 kHz
PB6
PB5
PB4
PB3
PD2
PB1
PB0
TXD
RXD
TRANSMIT
RECEIVE
B1
B2
TG4
TG1
TG2
TG3
CD4066
D1
C3
OPAMP 3
OPAMP 1
X AXIS
Y AXIS
Z AXIS
S1
S2
S3
L1
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26
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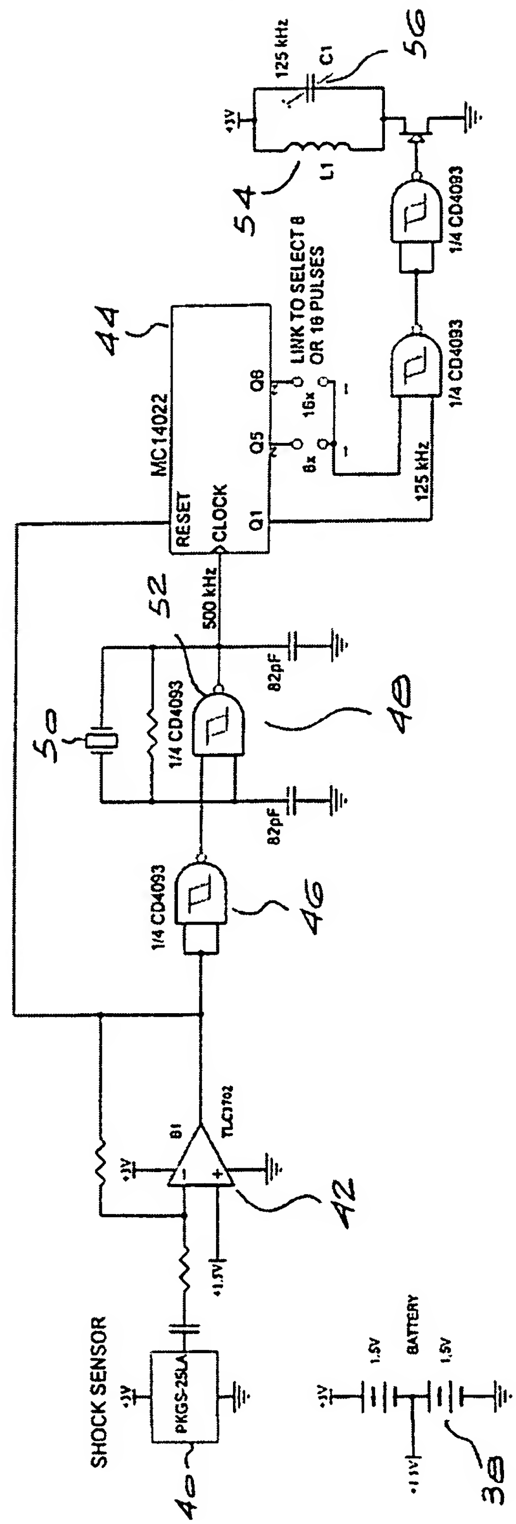
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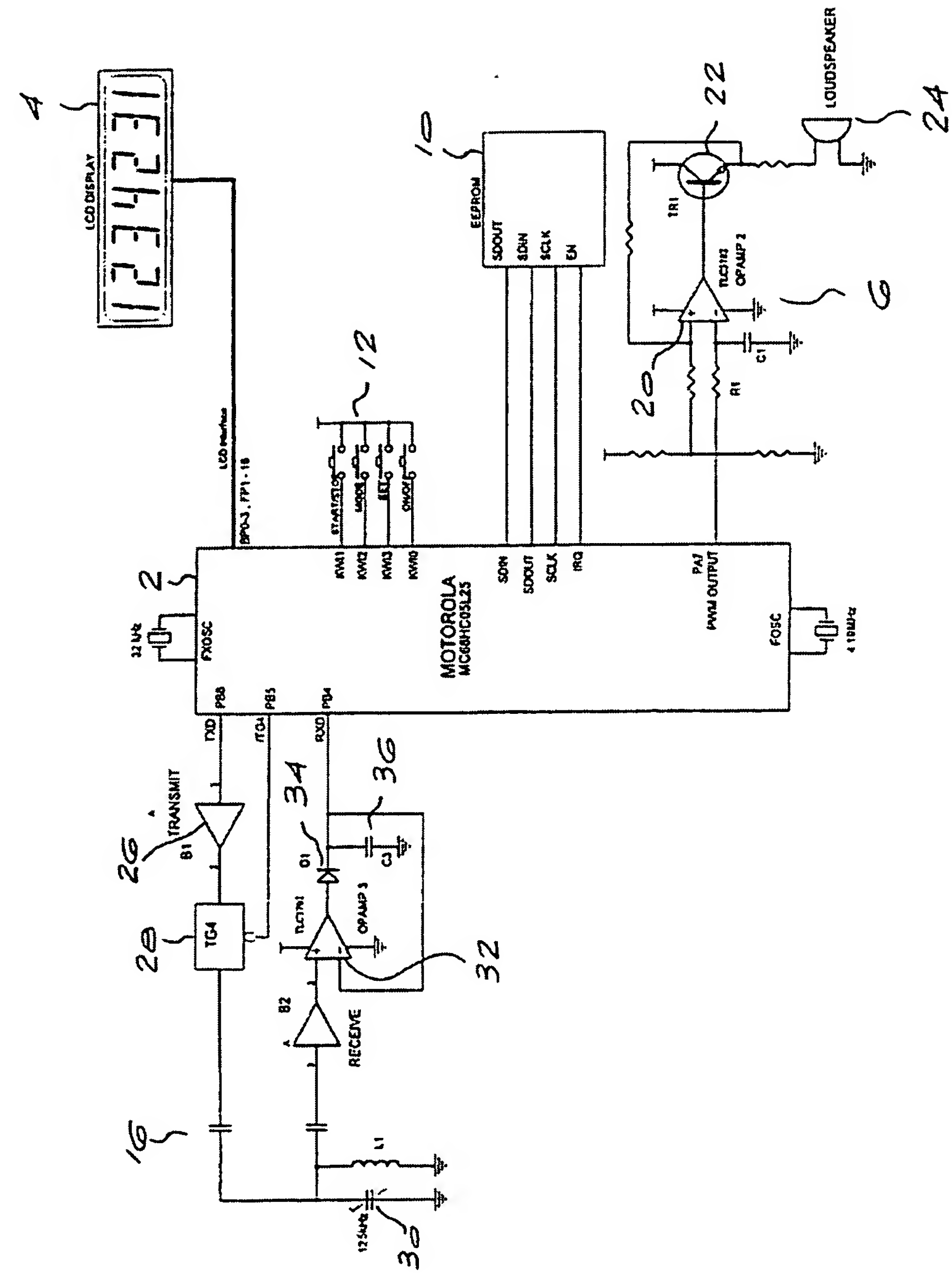
PKGS-25LA
TLC3702
B1
1/4 CD4093
82pF
500 kHz
RESET
CLOCK
MC14022
Q1
Q5
Q8
8x
16x
LINK TO SELECT 8
OR 16 PULSES
125 kHz
L1
C1
BATTERY
1.5V
+3V
+1.5V
40
42
46
48
50
52
44
54
56
38

FIG. 2


LCD DISPLAY
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SDIN
SCLK
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OPAMP 2
C1
R1
START/STOP
MODE
SET
ON/OFF
KWI1
KWI2
KWI3
KWI0
SDIN
SDOUT
SCLK
IRQ
PA7
PWM OUTPUT
FOSC
FXOSC
MOTOROLA
MC68HC05L25
PB8
PB5
PB4
TXD
RXD
TRANSMIT
B1
TG4
OPAMP 3
D1
C3
RECEIVE
B2
L1
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2
6
20
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24
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30
32
34
36

FIG 3

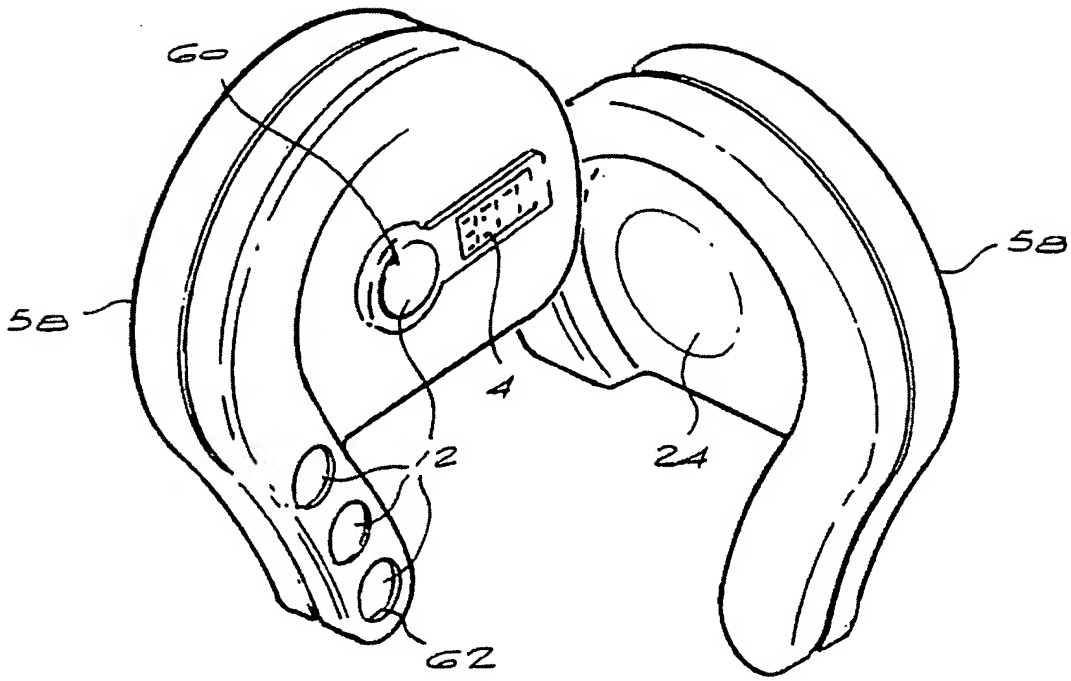

FIG 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 00/00579

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A63B69/00 A63B71/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A63B G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y		3
Y	WO 98 44358 A (PRECISION NAVIGATION INC) 8 October 1998 (1998-10-08) page 4, line 7 - line 22	3
X	US 5 685 722 A (TABA SERGE) 11 November 1997 (1997-11-11) column 2, line 63 -column 3, line 27 column 4, line 19 - line 63 column 5, line 3 - line 57 column 6, line 17 - line 26 column 8, line 41 - line 60	1,2,4-6
Y		7-12

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 August 2000	09/08/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Millward, R

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Interr   nal Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Inter   onal Application No
PCT/IB 00/00579

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